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A SCENARIO BASED METHODOLOGY FOR THE SELECTION OF NON-LETHAL WEAPONS

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The allocation of finite resources to develop non-lethal weapons for deployment as effective military assets is a difficult task considering that there exists a myriad of potentially promising technologies. Each proposed weapon has operational, logistical, and developmental advantages and disadvantages, which often do not appear self-consistent. Attempts to invent a common figure-of-merit often fail because it is difficult to avoid subjective criteria and evaluation. Ideally, an objective, consistent weapons selection methodology is required. We have developed a scenario based requirements methodology that allows us to highlight inter-scenario commonalties among the weapons considered. We have evaluated some thirty different anti-personnel and anti-material weapons considering over a dozen scenario based requirements including such criteria as effective range, weather susceptibility, cost, logistics and training. A selection matrix considering a requirement weight factor within a given scenario (e.g. MOUT, riot control) and performance comparison allows us to define overall weapon effectiveness within the context of the given scenario. Surprisingly, this scenario based analysis allows for an objective consensus evaluation of seemingly dissimilar weapons systems.

This system engineering approach commences with a functional decomposition of non-lethal capability and includes many subsystems, components, parts, and their tactical interactions. We seek to look for a *complete solution*, a solution that involves logistics, weapons suite, TTP (Tactics, Training & Procedures), C^4ISR, and life cycle cost. System engineering emphasizes integration from the beginning; thus avoiding stovepipes and sub-optimization. The principal of iteration in evaluating tradeoffs does not guarantee that all possible solutions are reviewed, but this scrutinizing methodology endeavors to optimize by quantifying essential criteria.

We seek an effective solution by first identifying the problem (i.e. what are the mission requirements?). Although the field of non-lethal weapon utilization is complex, crossing the spectrum of conflict (controversially the name itself stirs heated debate), a scenario driven approach helps isolate and identify the problem. Any scenario must be plausible, realistic, and relevant to the basic need (a non-lethal capability). These scenarios produce a list of broad system functions. Our analysis was based on the six scenarios from Non-Lethal Warfare Coordination Group [2]. The tactical requirements included functions such as: crowd control, incapacitate/stop crowds, stop a vehicle, and area control/denial. Actual specific requirements follow from these top-level functions. Some of these requirements will be specific to a particular scenario; such as effective range, countermeasure susceptibilities, etc. Other requirements may be common to all scenarios; life cycle cost, logistic requirements, etc.

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[2] Non-Lethal Warfare Coordination Group, under aegis of The Joint NLW Directorate. Scenarios included a preemptive strike, riot control, peace keeping, maritime interdiction and two military operations in urban terrain (MOUT) scenarios.

Scenarios Derived Requirements	
- Effective Range	- Effective Area
- Time to Effect	- Weapons Persistence
- Penetration Depth	- Target Selectivity
- Countermeasure Susceptibility	- Weather Susceptibility
- Non Lethality	- Environment Effect
- Life Cycle Cost	- Logistics
- Training	- Flexibility

Table 1. Requirements derived from NLW scenarios.

Table 1 list the requirements derived from the six NLW Coordination Group's scenarios. In addition to the scenario requirements, certain constraints must be considered in finding a solution. Constraints can include legal and ethical issues of non-lethal weapons employment.

Using the scenario derived requirements and system constraints, current and future technologies can then be evaluated. The evaluation review process of these non-lethal technologies must be iterative in nature. The iteration spiral of this evaluation involves the integration of non-lethal technologies into a military force structure (current military force structures or possible future structures) and then modeling the force structure performance in the selected scenarios. Scenario modeling provides feedback for the next evaluation cycle until the iteration eventually converges onto an optimum solution. The fundamental steps of the system engineering approach to non-lethal warfare are illustrated in figure 1.

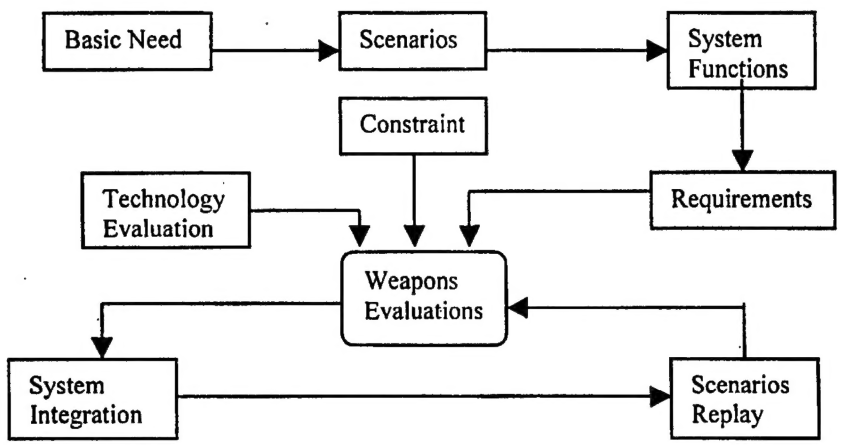

Figure 1: NLW system engineering block diagram

The evaluation methodology must be objective and consistent when applied to any weapon or weapon suite. A matrix evaluation method can be objective, consistent, and can easily be modified to many scenarios. Matrices allow quantitative results that will aide in systems comparison; furthermore, matrices can easily be expanded to evaluate technology as they arise.

The methodology of the evaluation matrix enables assessment of each non-lethal technology (weapon) in each scenario. The requirements are given weight factors (*Req WF*) to compare their relative effectiveness in each scenario. The weight factors are on a relative scale of 0 – 10 (10 high value). Each weapon is compared against each other in meeting each particular requirement and are given a weapon relative score (*Wep Relative Score*) of 0 – 10 (10 high value). The numerical effectiveness of a weapon (*Wep ReqEff*) in meeting a particular requirement is then defined as:

$$Wep\ ReqEff = (Req\ WF) * (Wep\ Relative\ Score).$$

The weapon's overall effectiveness (*Wep Eff*) in a scenario is defined as:

$$Wep\ Eff = \Sigma(Wep\ ReqEff).$$

Thus the weapon characteristics are evaluated against its peers in all requirement categories. These numerical results are good measure of effectiveness and are used for weapon selection. These mathematical relationships are illustrated in a sample matrix.

WEAPON TYPE	Eff. Range (100 m)	Flexibility
WEIGHT FACTOR	10	1
Low Energy Laser	10	7
MCCM	5	5
Baton	1	10

WEAPON TYPE	Eff. Range (100 m)	Flexibility	Scenario Score	Ranking
WEIGHT FACTOR	10	1	110	100.0%
Low Energy Laser	100	7	107	97.3%
MCCM	50	5	55	50.0%
Baton	10	10	20	18.2%

Figure 2. Sample matrix-illustrating weapon vs. requirement effectiveness. (MCCM = Modular Crowd Control Munitions)

The sample matrix illustrated the application of the evaluation methodology to a sample scenario where the requirement of a weapon's effective range of 100 meters was deemed very important; thus, this requirement was given the weight factor (*Req WF*) of 10. In this scenario the flexibility of the weapon was deemed not very important and was assigned a weight factor of only 1. The evaluation matrix highlights the relative strength and weakness of the three sample weapons in this particular scenario. A baton is a highly flexible weapon (scoring maximum *Wep Relative Score* of 10), but its poor effective range is detrimental to mission accomplishment. The low power laser is a weapon that is fairly flexible and has an effective range of 0 – 300 meters. The top matrix lists the raw scores of the three weapons in the scenario. The lower matrix shows the numerical results of the raw score. One can see that the low power laser is the optimal choice of the three because it was the only weapon that could effectively meet the critical effective range requirement. Although the baton scored better in the flexibility, this requirement had a weight factor of only one. The ranking column lists the normalized scenario weapon effective score for each weapon. The laser overall performance was much better than the other two.

The evaluation matrix generates numerical results that are consistent and objective. The input criteria (requirements weight factors and weapon's relative scores) are judgmental assessments. Various parties (military, political, and scientific) should be active participants in assigning the requirements relative weight factors. This is especially important because these requirements shall be the basis of weapon comparison. The defined requirements from table 1 are not all-inclusive and must be adaptable to different scenarios. The inputs of the military personnel, scientific community, and industry are absolutely critical to assigning weapons' relative scores. The weapon relative scores can readily be determined if the requirements are tangible and measurable quantities. For less "quantifiable" requirements (ie. flexibility, training, etc) where measures of effectiveness are debatable, weapon relative scores can be selectively subjective. The battlefield experiences of the military, in conjunction with input from the weapon laboratories and industry, can be utilized to make good and consistent scores. The iterative review process is essential here. Once these input parameters have been determined, the evaluation matrix methodology can be used to effectively assess any weapon in any single scenario or series of scenarios.

ANTI-PERSONNEL PHASE 1 (US FORCES IN THE STREETS - HOSTILE IN BUILIDINGS)

WEAPON TYPE	Eff. Range (300 m)	Eff. Area (room)	Time to Effect	Counter-measure Suscep.	Weather Suscep.	Non-lethality	Cost	Flexibility	Ranking
WF	10	8	6	8	8	2	6	7	100.0%
LOW ENERGY LASER	**90**	**64**	54	56	**64**	12	30	56	78.7%
STUN GRENADE	40	56	60	**64**	**64**	12	54	42	72.5%
GRENADES; PEPPER, CS, E	60	48	42	56	32	12	54	49	66.7%
MID SIZE, RIOT CONTROL D	**70**	**64**	42	56	32	12	54	14	65.4%
STICKY SHOCKER	40	16	54	56	56	12	30	56	62.2%
MCCM	40	8	42	56	32	12	54	56	58.8%
STUN GUN, ELECTRIC WIRE	**70**	16	54	40	**64**	10	30	28	57.9%
DIRECTED ENERGY	**100**	24	36	48	**64**	14	6	21	54.6%
STUN GUN, ELECTRIC FLUI	**70**	16	54	40	40	10	30	28	54.3%
ACOUSTIC JAMMING	10	16	54	56	32	10	30	21	42.5%

Figure 3. MOUT scenario matrix.

This scenario matrix applies to a military operation in urban terrain (MOUT), in which a US platoon must stop inter-clan fighting. The clans are fighting between buildings and there are also noncombatants present. The scenario derived requirements that are most important have weight factor of eight or greater, and are critical. If a non-lethal solution is possible in this scenario, it must be effective for these critical requirements. We have defined the requirement selection cutoff as any weapon numerical effectiveness score of 64 or greater (indicated by large, bold numbers). This cutoff value was chosen based on the product of *Wep Relative Score* ≥ 8 and *Req WF* ≥ 8. The matrix shows that no single weapon would be effective in accomplishing the mission. A combination of the low energy laser and stun grenades could achieve all four critical mission requirements. Despite the impressive effectiveness of the directed energy weapon in the effective range requirement, its poor performance in the other requirements makes it overall ineffective in the scenario.

MAN PORTABLE	
TOTAL SCENARIO SCORES = 5050	
WEAPON TYPE	
LOW ENERGY LASER	73.9%
STUN GRENADE	71.2%
GRENADES; PEPPER, CS, ETC	65.4%
MID SIZE, RIOT CONTROL DISP	65.4%
STICKY SHOCKER	64.9%
GRENADES, SPONGE	64.6%
AQUEOUS FOAM	60.6%
OBSCRUANT (SMOKE)	58.8%
STUN GUN, ELECTRIC WIRE	56.7%
RC - CLOSE QUARTER	56.5%
STICKY FOAM	56.3%

VEHICLE PORTABLE	
TOTAL SCENARIO SCORES = 5150	
WEAPON TYPE	
WEASEL	71.1%
RCADD	66.4%
MCCM	66.0%
WATER CANNON	62.3%
LF SONIC ENERGY	56.4%
DIRECTED ENERGY	53.1%
STUN GUN, ELECTRIC FLUID	54.6%
ACOUSTIC JAMMING	46.9%

Figure 4. Inter-scenario commonality, emphasizing anti-personnel weapon suitability for multiple scenarios.

The matrix evaluation methodology also allows us to observe inter-scenario commonality to avoid single scenario sub-optimization. Figure 4 depicts the total weapons effectiveness scores in all six scenarios. The *italicized weapons* are those that were chosen in one or more of the individual scenarios. These weapons consistently received high weapons effectiveness score in all six scenarios. The mid size

riot control dispenser was a weapon that consistently scored high in most scenarios, but was also consistently outperformed by one of the other weapons.

Another benefit of the matrix analysis is its ability to point out deficiencies in the evaluated technologies. After two iterations of all current and proposed non-lethal technologies in the six scenarios, it became apparent that there existed a need for a system that could deliver these effects onto the target without exposing friendly forces to potential hostile fire. A notional remotely operated, armored vehicle was proposed by the Naval Postgraduate School (NPS) study group to fill this gap. Similarly a riot control agent directional dispenser (RCADD) was another in-house creation to fill another gap in current and proposed non-lethal technologies.

ANTI-VEHICLES								
WEAPONS TYPE	Eff. Range (>20 km)	Eff. Area (field)	Time to Effect (ASAP)	Wep Persistenc	[illegible]	[illegible]	Weather Suscep.	Ranking
WF	10	10	4	8	10	[illegible]	5	100.0%
HP-MW MUNITIONS	**80**	**70**	36	**72**	50	63	45	75.4%
DEPOLYMERIZER	50	**80**	28	**64**	50	36	15	63.5%
POLYMERIZER	50	**80**	28	40	30	**72**	15	63.3%
DIRECTED RADIO FREQ	30	30	40	**64**	**70**	**81**	30	55.4%
DIRECTED MICROWAVE	10	10	40	64	**70**	**81**	30	50.6%
LASER	50	20	40	32	50	36	20	49.8%
DIRECTED EMP	10	10	40	**64**	40	**81**	40	45.9%
ROAD SENTRY	0	10	36	**72**	20	45	25	41.4%
VISCOSIFICATION	10	0	28	**72**	20	9	15	39.1%

Figure 5. Anti-Vehicles Preemptive Strike Scenario

The evaluation matrix can also show us if there are no feasible solutions to a particular scenario. The matrix in figure 5 is an evaluation of a non-lethal preemptive anti-vehicles strike. It may appear that the logical weapon suite should include the high-powered microwave munitions and a directed energy weapon. However, modeling this scenario with these weapons shows that the poor effective range and logistics requirements of a directed energy weapon renders this combination ineffective. Although the enemy can not easily counter the directed radio frequency weapon, our troops would have to maneuver a semi-truck sized weapon next to the target to be effective. This would certainly be unacceptable. Thus the matrix show us that the best we can do in this scenario is to a combination of the high power microwave munitions and a chemical attack to achieve most of the critical scenario requirements. Unless some new technology is developed we must accept the fact that the enemy may counter any weapon or combination of weapons used in this scenario. The evaluation can be a useful tool to focus research into areas where we are currently deficient.

In recent years the military has seen a tremendous number of proposed non-lethal technologies. Some of these promising technologies may comprise a tool kit capability that will expand mission situational dominance of the tactical officer in charge. The expanding utility of non-lethal weapons is critically dependent on the confidence gained through training and field employment. A system engineering analysis of the non-lethal tool kit will help differentiate the affordably promising and plausibly achievable from the science fiction. Furthermore, this outlined matrix approach can ascertain which weapon or weapon suite should provide the optimum solution, and if the same suite will be effective in various scenarios.